Polluted Streams Near Colorado Ski Resorts:
A Preliminary Study Using RiverTools

Scott D. Peckham
Research Systems, Inc.

Abstract

The Study Area

Nestled among 13000-foot peaks in the heart of Colorado, the scenery that surrounds the ski resorts in Summit County is so stunning that it might seem like the last place you'd find polluted streams. However, these same mountains are where the mining history of the state took place. Although most were abandoned long ago, these mines still contribute a steady stream of acid and heavy metals into otherwise pristine watersheds near the Continental Divide. One of the worst polluters is the abandoned Pennsylvania Mine, located in the Peru Creek subbasin of the Snake River basin in Summit County. Unfortunately, cleanup efforts have been stymied by a loophole in the Clean Water Act of 1972 (ammended by the Water Quality Act of 1987) that could hold those involved in a cleanup effort liable. So far, efforts to add a Good Samaritan clause to the Act have been unsuccessful. An estimated 22,000 abandoned mines are sprinkled throughout the state, with roughly 1,300 river miles suffering from severe water quality degradation.

In preparation for writing a grant proposal to study the area, I wanted to quickly learn as much as I could about the geography of Summit County and some of the affected watersheds. Using the RiverTools software from Research Systems, Inc. (RSI), I was able to learn a lot in a single afternoon, without most of the hassles that are usually associated with data acquisition and preparation, and without any programming. This included extraction of a flow grid and many of the other data layers that I would later need for further study and modelling of the local hydrology.

RiverTools is much simpler to use than a full-blown GIS, and has many built-in tools for doing things that are specific to the analysis of topography and river networks. However, it also has a suite of user-friendly command-line routines that can be used interactively in IDL for customized applications. (IDL, or Interactive Data Language, is the flagship product of RSI.) Furthermore, the data products created by RiverTools can easily be imported into a GIS or a customized model for further analysis. Here is a step-by-step outline of a small project that highlights the ease-of-use and a few of the novel features.

Downloading the Elevation Data

First, I used a hydrologic units map to find the bounding lats and lons for Summit County, Colorado. This map is available from the USGS and is called "Surface Water and Related-Land Resource Development in the United States and Puerto Rico." It shows the major river networks of the U.S. and is overlaid by lines of latitude and longitude with a 1-degree spacing. I found out

that the Snake River basins straddled two 1-degree cells, and that the southeast corners of these cells had a latitude of 39 and longitudes of 106 and 107. I then used the lookup table in the Prepare > USGS 1-Degree DEMs menu to get the corresponding USGS map names from the lat/lon codes of 39106 and 39107. Given these map names, I was able to quickly download the two USGS 1-Degree DEMs that I needed from the USGS EROS Data Center by anonymous FTP (edcftp.cr.usgs.gov). I uncompressed them with the free gzip utility. After decompressing, these ASCII files are fairly big, about 9.8 MB. Using the Prepare > Convert DEM dialog in RiverTools, it was easy to convert these DEMs to a much more compact binary format and create RiverTools info files (a metadata file) for them.

Reading and Displaying the Data

The next step was to create a DEM for the Snake River basin by mosaicking and subsetting the two 1-degree DEMs. RiverTools has a simple Add and Remove type of dialog for mosaicking DEMs called Prepare > Patch Fixed-Angle DEMs. This tool displays shaded relief mock-ups of the DEMs with seams, and then lets you select a subregion with a rubber-band box. Since these USGS DEMs contain an extra row and column, the dialog has check boxes that allow chosen edges to be ignored. (Note that the bounding box info in the info file should also reflect the extra row and column; e.g. the north edge latitude was 40.000833.) I selected the Snake River basin and then created a new DEM and info file for it with a single mouse click.

Before moving on to the extraction of other data layers, I created several shaded relief images of the DEM with the Shaded Relief dialog in the Display menu. I tried several different color schemes and light source angles, and also used several of the interactive window tools like the Line Profile, Surface Zoom, Value Zoom, Add Scale Bar, and Flood Image tools to explore the topography. (The Vector Zoom and Channel Profile tools can't be used until a flow grid has been created from the DEM.) The Line Profile tool can be used to measure distances, since it reports distance and elevation info in the log window. This showed, for example, that the Pennsylvania mine is a mere 5.7 km from Arapahoe Basin (across a divide) and only 13.4 km from the Keystone ski area, which is located downstream. Dillon reservoir, which is at the outlet of the Snake River basin, was apparently created after the USGS DEMs were made. However, I was able to "add it in" with the Flood Image window tool.

It was also a snap to create a nice rainbow-colored contour plot for the region, and to display it with various map projections and alternating black and white "box axes" around the edges. (See Figure.) This vector-drawn plot looked great when saved and printed as color PostScript.

Extracting Hydrologic Information

After less than a half hour of prep work, I was ready to begin extracting hydrologic information from my new DEM. The Extract menu in RiverTools contains many fast and easy-to-use dialogs for computing a treasure trove of derived quantities, starting with only a DEM. The first dialog in the menu is a one-button utility for computing a D8 (deterministic - 8 flow directions) flow grid from the DEM. This routine first creates a depressionless DEM, if necessary, and like the other extraction routines, can handle extremely large DEMs. The speed and one-step simplicity

are both impressive, especially for someone who has struggled to create flow grids with other software.

The next dialog in the Extract menu is a slick graphical tool for specifying the outlet location (as a pixel) for a basin of interest. You first click on a shaded aspect backdrop, and a streamline is drawn downstream from the pixel you selected to the edge of the DEM. You then move a slider to select a particular pixel in the DEM as an outlet from along this streamline. The location of the selected pixel is shown via a red/white interface on the streamline, and the lat and lon of the pixel are reported in a log window. (See Figure.) Once you've selected a pixel this way, you save the outlet information to a file with a mouse click. This outlet is then used for subsequent analysis (with other dialogs in the Extract menu) of the basin that drains into it. You can specify and analyze several basins in the same DEM this way, since each basin has its own "basin prefix" that can differ from the "data set prefix" that is used for the DEM and associated grids.
The View Basin Info dialog in the File menu gives a handy report of major basin attributes like drainage area (198.8 sq km for the Snake), relief, and outlet coordinates and elevation, etc. for the selected basin.

Using other dialogs in the Extract menu, I created a river network map and a basin boundary map from the flow grid. While creating the vector-based river map, a large number of attributes are automatically computed and archived in a vector format for each pixel, link and Strahler stream in the extracted river network. These include things like drainage density, Strahler order, channel length and slope, and contributing area. The Analyze menu has a large number of tools for analyzing and plotting this data. I also created several raster grids, including a flow distance grid and a topographic index grid. With the Surface Plot dialog in the Display menu I was able to drape these grids over a 3D surface plot. This was very useful for making a visual assessment of the surface geometry and for identifying regions that were most likely to become saturated with the spring snow melt.

Conclusions

While the analysis described above was exploratory in nature, I was able to learn a lot about my study area in a short amount of time. Since ski resorts in the area are proposing to extract more water from the Snake River for snowmaking, and since this polluted snow will eventually melt and run off into adjacent watersheds like Jones Gulch, I was particularly interested in the location of the Pennsylvania Mine relative to the ski resorts. Since runoff is roughly proportional to contributing area, the downstream dilution of contaminants is partially governed by the contributing area of the uncontaminated watersheds in the Snake River system. While RiverTools 2.0 rapidly computes many of the grids that are needed for a fully-distributed hydrologic model, the current version is geared toward the kind of fast and easy topographic analysis described above.